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COMPLETE SPECIFICATION

Method of Making Printed Circuit Board

We, MATSUSHITA ELECTRIC INDUSTRIAL CO. LTD., a Corporation organised under the laws of Japan, of 1006, Oaza Kadoma, Kadoma-shi, Osaka, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to a method of providing a metal layer on the surface of an electric insulating material, and more particularly to a method of making printed circuit boards.

A conventional method of making a printed circuit board is to provide a copper film layer on the surface of an electric insulating material, to apply etching resist on the copper layer in the form of the required electric circuit, and then to dissolve away the portions of copper layer that have no etching resist thereon by etching, the etching resist being removed thereafter.

The present invention is different from such a known method, in that only the electroconductive elements required are formed on the insulating plate, and consequently it has simple manufacturing steps, yet it assures the various characteristics required of a printed circuit board.

Another known method of making a printed circuit board is one in which metal powder is scattered onto the surface of an insulating base plate, on which an adhesive material has preliminarily been painted over the whole area, and then applying pressure thereon with use of a die in the form of electric circuit, whereby the metal powder is cold welded onto the base plate to form the conductor. The conductor in such a printed circuit board is the layer of metal powder. In accordance with the present invention, metal powder adheres to the surfaces of a adhesive material layer, covering the same and facilitating the subsequent chemical deposition of a metal layer in the form of a desired electric circuit, and also assuring strong adhesion of the metal layer to the base plate. It is to be noted that the metal powder layer is poor in electrical conductivity, the desired electrical conductivity being mainly provided by the chemically deposited metal layer.

Another known method of making a printed circuit board is one in which a mixture of metal powder and adhesive material is painted or printed on the surface of an insulating base plate in the form of a desired electric circuit. However, in such a printed circuit, required conductivity may be hard to obtain and, in addition, soldering of other circuit elements to the printed circuit is difficult to effect. Metal material may be plated on the printed circuit of the mixture of metal powder and adhesive material in order to obtain good conductivity, but it is very difficult to provide a sufficient amount of metal powder exposed on the surface of the layer of the mixed material to effect the metal plating, which metal plating can be accomplished only after the surfaces have been abraded mechanically. Such a method is, therefore, of poor practicability. Metal may alternatively be electrically plated or chemically plated by a substitution reaction on a metal powder layer secured to an insulating base plate by an adhesive

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material, but in a printed circuit board, many individual electric circuits are generally to be formed on a base plate and consequently electrical plating becomes a very complicated process, not suitable for mass production. Chemical plating by a substitution reaction may be possible, such as by silver plating on copper powders or copper plating on iron powders. However, chemical plating by a substitution reaction is, in general, extremely difficult to regulate, so that deposited metal is apt to take the form of coarse particles, resulting in a weak metal layer. Further in such a reaction, the base metal is partly dissolved naturally, simultaneously with the deposition of desired metal, and the deposited metal is prevented from intimately uniting with the base metal. In addition, after the base metal has been covered by the deposited metal, a substitution reaction cannot take place and consequently, the layer of deposited metal is often not sufficiently thick to serve as a conductive layer. Thus, a printed circuit board made by this method has a conductive layer which has a poor adherence to the base plate, and a poor mechanical strength, so that the conductive layer is apt to be damaged by, for example soldering. Thus, such a printed circuit board cannot be said to be of good reliability. In these above described known methods, since the deposited metal particles are generally coarse, or an ample and efficacious thickness of the metal layer is difficult to obtain, a strong metal film layer cannot be formed. Thus, such printed circuit boards as have heretobefore been known have a poor mechanical strength and are liable to have their plated metal layers broken or damaged by soldering thereto of other circuit elements, resulting in very poor reliability in connection thereto of the other circuit elements.

The present invention aims to overcome the abovementioned various disadvantages of the known methods of making printed circuit boards. To this end, this invention comprises painting or printing a circuit pattern with an adhesive material on an electrically insulating base plate, scattering metal powder on the plate to cover the painted or printed area (which powder is preferably capable of serving as catalyst for a subsequent chemical reducing reaction), adhering the metal powder to the adhesive material by means of a suitable pressure applied thereto, removing if necessary, metal powders not adhering to the adhesive material, optionally hardening the adhesive material, for example by heating, and depositing metal on the remaining powder by means of a chemical reducing reaction. The metal powder particles are partly embedded in the adhesive material layer, so that they are strongly secured to the base plate by the adhesive material, and at the same time, they are partly exposed on the surface of the adhesive material to enable them to serve as a catalyst for the subsequent chemical reducing reaction. Metal deposited on the surface of the metal powder layer by the chemical reducing reaction is composed of dense, extremely minute particles. The deposited metal does not adversely affect the base metal powder, and becomes integrated with the base metal powder particles which thus serve as cores. This invention enables the attainment of a product similar to an insulating base plate having a metal film layer bonded thereto by the use of an adhesive material, the metal film layer having many convex and concave portions and consequently mechanical strength with strong bonding of conductive layers to the base plate, great mechanical strength of the conductive layer, and superior soldering ability. Thus, in addition to electrical characteristics, the printed circuit board produced according to the present invention is satisfactory in, for example, mechanical strength and soldering workability for securing thereto other electrical parts.

The present invention will be more fully understood from the following detailed description taken in connection with the accompanying drawings, in which:

Figures 1—5 are partial sectional views of a printed circuit board structure in respective steps of the method of making it in accordance with the present invention;

Figure 6 is a partial sectional view of a modified printed circuit board made in accordance with the present invention;

Figures 7, 8 and 10 are partial sectional views of modified printed circuit boards made in accordance with the present invention;

Figure 9 is a partial sectional view of the printed circuit board structure of Figure 10 at a stage during its manufacture in accordance with this invention.

The electrical insulating base plate 1 (Figure 1) employed according to the present invention may be various kinds of synthetic resin plates and synthetic resin laminated plates, for example, having the necessary electrical and mechanical properties, chemical resistance and heat resistance. The most popular base plate is a laminated plate of a phenol resin. An adhesive material 2 (Figure 2) is painted on the base plate 1 in the form of a desired electrical circuit by any of various painting methods, but it is desirable to prepare an ink in which suitable printing adaptability is imported to the adhesive material, and to apply the ink to the base plate by a silk screen printing process. The adhesive material may be, for example, an epoxy resin or a phenol resin, capable of having, for example, suitable printing adaptability, chemical resistance and heat resistance.

Metal powder 3 is scattered onto the surface of the base plate 1 having the adhesive material 2 printed thereon in the form of a desired electrical circuit, as shown in Figure

3. The metal powder should have such a nature that it can serve as a catalyst in the subsequent chemical reducing reaction. The metal powder may be selected from the group consisting of powdered silver, copper, iron, nickel, cobalt, gold, platinum, palladium, aluminium, beryllium, rhodium, their alloys, and particles plated with such metals. The powder should preferably have a generally dendrite shape. The particle size of the metal powder used is preferably 10 to 100μ. The metal powder is preferably scattered as evenly as possible. After the metal powder has been scattered, a suitable pressure is applied thereon such that the adhesive material in the form of the electrical circuit retains the powder and is not deformed. A press may be used to provide the necessary pressure. Also a pair of rollers, for example rubber rollers, may be employed for passing therebetween the assembly shown in Fig. 3. One of the rollers may be driven by a power means, the other roller being used to bear on the powdered surface of the plate.

Metal powder not adhering to the adhesive material 2 is removed, and the adhesive material is cured or hardened to secure the metal powder adhering thereto as shown by 4 in Fig. 4. The removed metal powder may be recovered for re-use. By suitably selecting the thickness of the painted or printed layer of adhesive material, the shape and size of the metal powder particles and the pressure conditions, the metal powder can be secured to the adhesive material in intimate adhesion therewith, with individual metal powder particles partly embedded in the adhesive material and partly exposed beyond the surface of adhesive material layer. Thus, the metal powder is strongly fixed on the base plate by the adhesive metal and, at the same time, it enables the deposition of metal by means of the chemical reducing reaction.

Copper, nickel or any other suitable metal may be deposited by the chemical reducing reaction on the metal powder fixed to the insulating base plate by means of the adhesive material as hereinbefore described. The invention will be explained further taking copper as an example of the deposited metal.

An insulating base plate having the metal powder fixed thereto as hereinbefore described and shown in Fig. 4 is immersed in an alkaline solution of a complex salt of copper containing formaldehyde added thereto as a reducing agent. Copper ions in the solution are reduced by the formaldehyde to deposit metallic copper, and since the metal powder, for example silver or copper, fixed to the insulating base plate serves as a catalist in the above reaction, the copper deposition onto the metal powder is accelerated. Consequently, if appropriate reaction conditions are selected, it is possible to have copper 5 deposited onto the metal powder 4 only, as shown in Fig. 5. Alternatively, for example, nickel may be deposited in place of copper, in which case a nickel salt solution may be used containing sodium hypophosphite as a reducing agent, into which is immersed the base plate having the metal powder layer fixed thereto in the form of the desired electric circuit. A nickel or iron metal powder layer is preferably used in this case.

One of the important features of the present invention is that a predetermined metal should be deposited by means of the chemical reducing reaction only onto the metal particles fixed to the insulating base plate. However it is to be understood that the invention is not limited to particular reaction conditions, such for example as the formation of a plating solution, for improving various characteristics, such for example as the deposition rate of the metal or the stability of the plating solution.

The metal deposited as above described forms an extremely dense layer and is bonded strongly with the base metal powder fixed to the insulating base plate, and in addition, such metal powder is strongly bonded by the deposited metal layer. As a result, a great mechanical strength is obtained, and soldering of external parts or elements to the metal layer can be effected with ease and safety, just as in the case of ordinary metal foil fixed to a base plate. Since the layer of metal deposited by the reducing reaction is fixed to the insulating base plate through metal particles partly embedded into the layer of adhesive material, it is very strongly bonded to the base plate.

The invention will now be further illustrated by way of example.

Example 1

To 30g of epoxy resin consisting of 20g of Achmex R-11 and 10g of Achmex H-85 was added 3g of carbon to obtain an adhesive material. On an insulating base plate of a phenol resin laminate a desired form of electrical circuit was printed with the adhesive material by a silk-screen printing process. Copper powders of 10 to 100μ particle size were then scattered onto the layer of adhesive material to a thickness of 1 to 2 mm, and a pressure of 0.5—1.0 tons/cm^2 was applied thereon to secure the copper particles to the adhesive material. Copper particles not secured to the adhesive material were removed, and the adhesive material was hardened by heating it at 150$\pm$10°C. for about one hour. After preliminary treatments, for example water rinsing and acid rinsing, the plate was immersed in a solution of the following formation at 25°—35°C., in order to deposit copper onto the above-mentioned copper particles:—

copper nitrate	8.0 g
potash soda tartrate	15.0 g
caustic soda	10.0 g
formaldehyde (36%)	40 ml

The above constituents were dissolved into an appropriate amount of water for forming 1 *l* of the solution as a whole.

After a predetermined amount of copper had been deposited by the reducing reaction, the plate was taken out of the solution, washed with water and polished to complete the printed circuit board.

EXAMPLE 2

A desired form of electric circuit was printed on a phenol-resin laminated plate with an adhesive consisting of a phenol resin, benzyl alcohol and carbon by a silk-screen printing process, and iron particles of about 10 to 100μ size were scattered thereon to a thickness of 1—2 mm. After application of a pressure of 0.5—1.0 tons/cm^2, iron particles not adhering to the adhesive material layer were swept away, and the adhesive material was cured by heating at 150°±10°C. for about one hour. After preliminary treatments, for example water washing and acid washing, the plate was immersed in a solution of the following formation at 80°—100°C.:—

nickel chloride	30 g
sodium hypophosphite	10 g
sodium citrate	15 g

water to form 1 *l* of solution as a whole. After a predetermined amount of nickel had been deposited, the plate was taken out of the solution, washed and polished.

Several modifications of the basic process of the present invention hereinabove described will now be explained.

In order to strengthen the joint of, for example, a lead wire to be soldered to the printed circuit through a hole in the base plate, a metal layer may be formed continuously from a conductor on the surface of the insulating base plate and on a portion of the hole to enable solder material to enter the hole, thus ensuring positive and strong solder jointing and also reinforcing the attachment of the lead wire to the printed circuit plate.

Referring to Fig. 6, a hole A for the insertion of parts is formed through the insulating base plate 1 having requisite electrical characteristics as well as mechanical strength, by drilling or by punching. Punching is preferred, as the hole formed thereby has somewhat rounded edges advantageous for the subsequent step of working. A layer of adhesive material 2 is formed in the shape of the desired electrical circuit on the base plate 1 in the manner hereinabove described, the base plate having holes A for lead wire insertion formed at predetermined positions in the electrical circuit. At this time, the adhesive material is applied to the surface of base plate 1 and also to a portion of the inner wall surface of holes A for lead wire insertion as shown by reference number 2′. Metal powder is then scattered onto the adhesive layers 2 and 2′, to serve as a catalyst in the subsequent chemical reducing reaction for the deposition of conductive metal, and mechanical pressure is applied to the adhesive material layer, as hereinabove described, for positively securing the metal powder layers 4 and 4′ to the adhesive material layers 2 and 2′, respectively. The adhesive material layers are then hardened to fix the metal powders to the base plate. Subsequently, conductive metal layers 5 and 5′ are formed on metal powder layers 4 and 4′ by the chemical reducing reaction hereinabove described. With the metal layer 5′ thus formed partly in holes A in continuation with the circuit layer 5, soldering lead wires that are inserted into the holes A, is effected over the layer 5 as well as layer 5′, thus affording increased strength.

A conductive layer may be formed on the whole inner wall surface of hole A, as shown in Figs. 7 to 10, in order to provide increased reliability for positive soldering of lead wire. This is particularly advantageous when printed electrical circuits are formed on opposite surfaces of the base plate 1 and are electrically connected to each other through the conductive layers on the walls of the holes in the plates. In the example shown in Fig. 7, the insulating base plate 1 has smooth surfaces. In this example, after provision of holes A, one of which is shown in Fig. 7, an activating treatment is effected for facilitating metal deposition by the subsequent chemical reducing reaction. Various activating treatments may be employed, but in this example, the base plate 1 was immersed in stannous chloride solution and palladium chloride solution, successively. This activating treatment is effected for the base plate 1 as a whole, but since the base plate has extremely smooth surfaces, the activity imparted by the treatment to the surfaces of base plate 1 can readily be removed of by water washing, brushing or like sweeping or rinsing, and the inner wall surface of hole A only preserves the activated layer 12. An adhesive material layer 2 is then formed on the surface of base plate 1 in the desired form of electric circuit, with the hole A positioned at a predetermined point in the layer 2, and catalytic metal powder, copper powder for example, is scattered onto the adhesive layer 2 and pressed thereto to form metal powder layer 4. The subsequent chemical reducing reaction for effecting the deposition of the conductive metal layer is effected, in this example, by immersing the plate in a liquid mixture of an alkaline solution of a copper complex salt and formaldehyde. As a result, copper is deposited on the copper powder layer 4, the copper powder serving as catalyst, while, on the activated layer 12, copper is also deposited, with the layer 12 acting as a catalytic core. Thus, a conductive metal layer 5 is formed simultaneously on both copper powder on the

base plate and the activating layer 12 on the hole surface.

In the example shown in Fig. 8, the surfaces of base plate 1 are not smooth and they retain activated layer 12 formed by the above described activating treatment even after water washing and rinsing. In this case, the surfaces of base plate 1 are painted with an insulating paint 13, with the activated layer 12 in the hole A only exposed. Then, adhesive material 2 is applied on the insulating layer 13 in the form of the desired electric circuit, catalytic metal powder is scattered on the adhesive material layer 2 and pressed thereon to form metal powder layer 4. After hardening of the adhesive layer, the plate is immersed in a liquid mixture of a metal salt solution and a reducing agent to effect the chemical reducing reaction for depositing conductive metal layer 6 on the metal powder layer 4 as well as on the activated layer 12 in the hole A.

In the example shown in Fig. 9, the insulating base plate 1 also has rough surfaces which cannot be worked to make the surfaces smooth enough. In this example, a soluble paint 13 is first applied to the surfaces of base plate 1, and then holes A for lead wire insertion, only one of which is shown, are formed therethrough. Thereafter, activated layers 12 and 12′ are formed by the aforementioned activating treatment on the surfaces of base plate 1 as well as on the inner surfaces of holes A. If the soluble paint layers 13 are then removed, the activated layers 12 on the surfaces of base plate 1 are also removed along with layers 13, but the activated layers 12′ are left, as shown in Fig. 10. Adhesive material layer 2 is then applied to the base plate 1 in the form of the desired electrical circuit, whereafter catalytic metal powder layer 4 is applied to the layer 2. After the adhesive layer 2 has been hardened, the plate is immersed in a liquid mixture of a metal salt solution and a reducing agent, for depositing conductive metal layer 6 simultaneously on the metal powder layer 4 as well as on the activated layer 12′.

As has been illustrated in the foregoing description, a conductive metal layer may formed on the inner surfaces of holes A for insertion of parts and on the surface of a metal powder, for example copper powder in the form of a desired electric circuit on the base plate simultaneously and in continuation, so that process of this invention may be simple and easy to effect. In addition, soldering of lead wires of parts can be effected, with solder material entering into the holes A entirely, and the reliability of soldered joints is thus remarkably increased. Further, when electrical circuits are printed on both of the opposite surfaces of the base plate, they may be connected together through the conductive metal layer on the inner surface of holes A.

WHAT WE CLAIM IS:—

1. A method of making a printed circuit board comprising printing or painting a circuit pattern on a surface of an insulating plate in an adhesive material, scattering metallic powder on the plate to cover the printed or painted area, applying a pressure thereon to make the powder adhere to the adhesive material and subsequently removing any powder not so adhering, and depositing metal on the remaining powder by means of a chemical reduction reaction process so as to form the printed circuit.

2. A method according to claim 1 wherein the resultant layer of deposited metal has sufficient thickness to enable soldered metal junctions to be formed therewith.

3. A method according to claim 1 or claim 2 wherein the metal powder is chosen so as to act as a catalyst in the aforesaid reduction process.

4. A method according to claim 1, 2 or 3 wherein the adhesive material is applied to the surface by a silk screening process.

5. A method according to any preceding claim wherein the adhesive material is hardened immediately after removing any metallic powder not adhering to the adhesive material.

6. A method according to any preceding claim wherein pressure is applied to the powdered plate by passing it through the nip of a pair of rollers, the pressure being limited so as to avoid disturbing the printed or painted circuit pattern.

7. A method according to claim 6 wherein one of the rollers is driven by a power means, the other roller being used to bear on the powdered surface of the plate.

8. A method according to any preceding claim wherein the metallic powder comprises at least one of a group consisting of nickel, copper, silver, gold, platinum, palladium, their alloys and particles having such metals plated on them.

9. A method according to claim 8 wherein the adhesive is hardened immediately after removing any metallic powder not adhering thereto, and the plate is then immersed in a liquid mainly comprising an alkali solution of copper complex salt and formaldehyde, which formaldehyde acts as the reducing agent in the reducing reaction process, there being copper deposited as a layer on the adhesive as a result of the reaction process.

10. A method according to any one of claims 1 to 7 wherein the metallic powder comprises at least one of the group consisting of iron, nickel, cobalt, aluminium, beryllium, platinum, palladium, rhodium, their alloys, and particles having such metals plated on them, and wherein the adhesive is hardened immediately after removing any metallic powder not adhering thereto, and the plate is immersed in a liquid mainly comprising a nickel salt solution and a hypophosphite, which

hypophosphite acts as a reducing agent in the reduction reaction process, there being nickel deposited as a layer on the adhesive as a result of the reaction process.

11. A method according to any preceding claim including the initial step of forming a hole in the plate in such a position as to provide in the finished circuit board a socket in a predetermined position for the insertion of a connector of an external circuit element, and wherein the method is adapted so that the conductive metallic layer formed on the adhesive extends along the wall of the hole.

12. A method according to any one of claims 1 to 10 including the initial steps of rendering the surfaces of the plate smooth, forming a hole in the plate in such a position as to provide in the finished circuit board a socket in a predetermined position for the insertion of a connector of an external circuit element, immersing the plate in a solution of stannous and palladium chloride respectively so as to provide an activated surface to the wall of the hole on which metal will deposit from one surface of the plate to the opposite one during the reduction process, and removing the activation on the latter surfaces of the plate by washing, polishing and/or brushing or the like.

13. A method according to any one of claims 1—10 including the initial steps of forming a hole in the plate in such a position as to provide in the finished circuit board a socket in a predetermined position for the insertion of a connector of an external circuit element, immersing the plate in a solution of stannous and palladium chloride respectively so as to provide an activated surface to the wall of the hole on which metal will deposit from one surface of the plate to the opposite one during the reduction process, and covering the surfaces of the plate except the surface of the hole with an insulating paint.

14. A method according to any one of claims 1—10 including the initial steps of covering the plate with soluble paint, forming a hole in the plate in such a position as to provide in the finished circuit board a socket in a predetermined position for the insertion of a connector of an external circuit element, immersing the plate in a solution of stannous and palladium chloride respectively so as to provide an activated surface to the wall of the hole from one surface of the plate to the opposite one during the reduction process, and removing the soluble paint from the surfaces on which it was painted so as to remove the activation from the said surfaces but leaving it on the wall of the hole.

15. A method according to any preceding claim wherein the adhesive is hardened immediately after removing any metallic powder not adhering thereto and the surface on which the circuit pattern is printed or painted is washed.

16. A method according to claim 15 wherein the washing process includes an acid rinsing.

17. A method of making a printed circuit board according to claim 1 substantially as described with reference to the specific examples and the accompanying drawing.

18. A printed circuit board made by the method according to any one of claims 1 to 17.

19. Apparatus including a printed circuit board according to claim 18.

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1095117 COMPLETE SPECIFICATION

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